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ABSTRACT

This guide was developed to provide children with an opportunity to prepare and collect several common gases and to discover and work with some of their properties. The guide is divided into five major sections: (1) introduction, (2) materials, (3) activities, (4) balloons aloft, and (5) an appendix. The introduction provides information concerning use of the guide, grade level, scheduling, and evaluation. The materials section lists materials needed for this unit. The activities section describes activities involving bromothymol blue, carbon dioxide, oxygen, hydrogen, and mystery gases. The Balloons Aloft section describes a concluding activity. The appendix provides information on safety precautions, preparations, recipes and techniques, and the yardstick balance. (DS)

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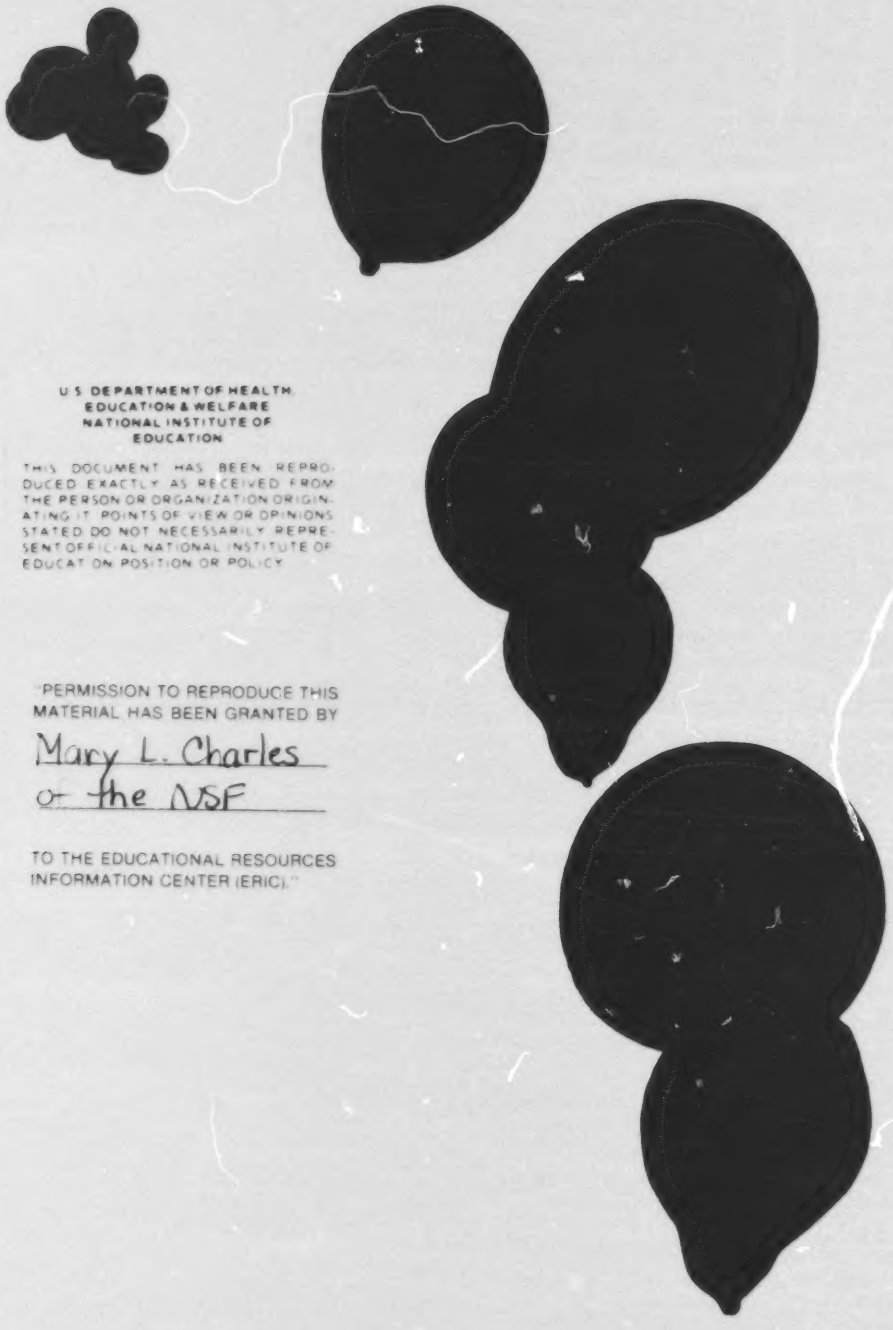
Teacher's Guide for
Balloons and Gases



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Teacher's Guide for

Balloons and Gases

Elementary Science Study

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The Balloons and Gases Unit
Teacher's Guide for Balloons and Gases
Class Kit I
Class Kit II

Related Units
Gases and "Airs"
Mystery Powders
Clay Boats
Sink or Float
Senior Balancing

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Preface

The Elementary Science Study is one of many curriculum development programs in the fields of science, social studies, and mathematics under preparation at Education Development Center, Inc. EDC (a private nonprofit organization, incorporating the Institute for Educational Innovation and Educational Services Incorporated) began in 1958 to develop new ideas and methods for improving the content and process of education.

ESS has been supported primarily by grants from the National Science Foundation. Development of materials for teaching science from kindergarten through eighth grade started on a small scale in 1960. The work of the project has since involved more than a hundred educators in the conception and design of its units of study. Among the staff have been scientists, engineers, mathematicians, and teachers experienced in working with students of all ages from kindergarten through college.

Equipment, films, and printed materials are produced with the help of staff specialists, as well as of the film and photography studios, the design laboratory, and the production shops of EDC. At every stage of development, ideas and materials are taken into actual classrooms, where children help shape the form and content of each unit before it is released to schools everywhere.

Acknowledgments

The idea for this unit originated when William Bertozzi first tried some of the activities with children in the summer of 1965. The following year he, Gerald Wheeler, and Robert Gardner modified the equipment and activities for further teaching and prepared a draft of a teacher's guide. This was taught on a limited basis and was revised by Gardner and issued as a Trial Teaching Edition, called *Balloons*, in the spring of 1968. The unit has been revised considerably on the basis of trial teaching.

Sister Lucy Malarkey of the Mayfield School in Pasadena, California, contributed heavily to the present edition. She taught several different versions of the revised *Guide* and helped with developmental work. Her classroom notes were wonderfully detailed and helpful.

The entire ESS staff lent editorial assistance for this writing. Edith H. E. Churchill and Emily Romney made many helpful and astute suggestions. Frank Watson shared with me his experiences in classrooms and workshops. Adeline Naiman provided editorial assistance and much encouragement. Mary S. Gillmor contributed in too many ways to mention.

The photographs were taken by Joan Hamblin, Major Morris, Sister Jacqueline Jelly, and Sister Alice Callaghan.

Joe H. Griffith

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Introduction

There are many ways to learn things, and only one of them involves reading a b[illegible]. Science deals with the behavior of the real world. Doing experiments, watching things happen, observing animals—all these activities are "lessons," richer in content than any textbook.

Gases are often very mysterious to children, because a gas may be invisible and yet have properties that can be observed. Adults take the existence and diversity of gases for granted, but for many children the spaces in the world are filled with "nothing." It is a big jump to go from this nothing to a *something* called air. It is an even bigger jump to realize that air is made up of several kinds of gases and to think of ways to tell different gases apart.

BALLOONS AND GASES provides children with an opportunity to prepare and collect several common gases and to discover and work with some of their properties.

If you follow the sequence suggested in the *Guide*, the students work first with acids and bases and with the colored indicator bromothymol blue (BTB). These activities give experience with a few simple chemical reactions and with some of the properties of acids and bases. Furthermore, they introduce students to a method for distinguishing between fluids that look alike.

Next, students generate gases that are "invisible." They try to identify and differentiate between these by weight, by the reactions of the gases to a solution of BTB or limewater, by their effect on a flame, and by other indications.

Generating and trying to identify mystery gases on the basis of their earlier experience carries the students a step further in their investigations.

There is a logic to the sequence of activities in the *Guide*, but there has been no attempt to provide for all students' responses or to encompass all the possible questions that are interesting and worthwhile to explore. If you treat the activities as a series of lessons to teach or as experiences for your students to work through in order and then "finish," you and they will miss much of the unit's richness. If the equipment is available, the students will come back, at later times and in different ways, to those questions and experiments that intrigue them.

In this unit, students will be able to control many different chemical reactions. The ones by which the gases are generated and identified suggest a whole range of related questions and explorations. For example, students may want to look more closely at—

1. The behavior of BTB as a color indicator
2. How the proportions of the ingredients affect the amount of gas that is produced
3. The way a catalyst acts to produce a gas, as in the case of potassium iodide and hydrogen peroxide
4. Dry Ice—as a starting point for investigating the same substance in different states, and the striking change in volume which occurs when a substance changes from a solid to a gas

5. Questions relating to buoyancy and density, which often arise when students compare a heavy carbon dioxide balloon and a floating hydrogen balloon (How much does the hydrogen weigh?)

Any one of these or similar topics may become the focus of the activities of some or all students at particular times. Their own ideas and interests are often the best guide to rich learning experiences.

One further note: Some teachers have found it helpful for students to work through **BALLOONS AND GASES** before they undertake the ESS unit **GASES AND AIRS,** which looks at similar questions in a more sophisticated way.

Using This Guide

Before you teach **BALLOONS AND GASES**, read through this *Guide* and try out some of the activities and experiments for yourself. Some teachers feel that their preparation to teach these science materials is inadequate and that they should use only topics with which they are familiar. If you feel this way, you may be relieved to know that some of the best learning situations occur when the teacher is "discovering" along with the students. You need to have the materials carefully prepared and available, but you don't need to have all the answers.

The Appendix contains important safety precautions and instructions for assembling some of the equipment. Also included are directions for making the three gases (oxygen, hydrogen, and

carbon dioxide), for doing certain tests, and for collecting gases. Some of the items in the Appendix repeat items in the text. The Appendix is meant to provide a quick reference in which you can find recipes and instructions gathered all together.

The *Guide* does not provide you with many explanations about the chemical reactions and properties exhibited by the materials. The omission is intentional. The value of these materials lies in the students' using them with pleasure to find answers by experimenting and observing. Refer to a chemistry textbook for detailed chemical explanations of your students' investigations if you feel you need them.

In trial classes, BALLOONS AND GASES has been taught successfully in the sequence offered in the *Guide*. There is, however, nothing sacred about this order, and you should feel free to alter it if you prefer another sequence or if the students' investigations suggest a different order in your class. You may, however, want to follow the *Guide* the first time you teach the unit.

A number of questions related to the activities are included in each section. How you use them is up to you. They are not necessarily to be "answered." Perhaps they will help you further the interests of particular students or ask stimulating questions of an experimenter who needs help.

There will be times when you will want to bring a few students or the whole class together to share their results and pause to consider what others are doing. You and your students must judge when class discussion is useful and when it would be an interruption.

Here are a few suggestions about sharing ideas that may be helpful:

- Full-class discussions are only rarely successful. Usually only a few articulate students do the talking, while others get lost or "turn off." So keep large-group discussions or presentations brief.
- Students often don't hear one another. At some point, it might be useful to pair off students and have them interview each other. Results of these interviews could be shared with the class orally or in writing.
- Often the class will divide into a fast group, many of whom already know about gases (these are often boys), and a slower group of students who work methodically. It might be useful to have separate group discussions. Sometimes a measure of isolation gives students who work more slowly the confidence to continue at their own pace, even if others are far ahead.

Grade Level and Scheduling

The activities in the *Guide* will take between twelve and twenty class periods of about an hour each. The unit can go longer if students become interested in further investigations.

BALLOONS AND GASES has been taught successfully in grades five through eight. The initial activities (working with BTB, vinegar, ammonia, baking soda, and citric acid) are fun for people of all ages.

Evaluation

How are you going to find out if this unit has done anything for your students? You can ask them, and you can watch.

What each student learns from this unit will depend in large part upon the effort he puts into the work. Students will differ on what things strike them as interesting.

There are several things you might look for as evidence of learning. Are the students interested in what they are doing? Do they suggest different things to investigate that you haven't mentioned? Do they do related things at home? Do they get involved in their own experiments?

The last activity of this unit, Mystery Gases, can be used as a kind of evaluation. The way the students tackle a new problem or look at a new experiment will give you some indication of the extent to which they can make use of their earlier experiences with gases. Whether or not they identify the gas is not as important as their having the confidence to tackle the problem.

Materials

CLASS KIT 1 (NONEXPENDABLES)

This *Kit* contains laboratory equipment which can be reused many times. Most of the items are available separately only through chemical supply houses.

- 15 *Erlenmeyer flasks*
- 32 *1-hole rubber stoppers (to fit the flasks)*
- 16 *4-in. stiff plastic tubes*
- 10 *2-oz plastic dropper bottles with caps*
- 20 *4-oz plastic dropper bottles with caps*
- 250 *1-oz plastic graduated medicine cups*
- 30 *one-piece vinyl droppers*
- 40 *½-tsp measuring spoons*
- 20 *½-pt plastic containers with snap-on lids*
- 6 *3-ft lengths of flexible vinyl tubing (⅛ I.D.)*
- 15 *pairs of safety glasses*
- 30 *flexible plastic vials (⅝" × 1")*
- 2 *1-qt polyethylene narrow-mouth bottles with screw caps*
- 4 *1-pt polyethylene narrow-mouth bottles with screw caps*
- 1 *hand pump (to blow up balloons)*
- 1 *set Multi-Purpose Balance parts*

CLASS KIT 2 (EXPENDABLES)

These are all expendable items. To replace them locally might require considerable effort. In order to teach **BALLOONS AND GASES** a second time, you should need to reorder only this *Kit*.

- 2 *gross round balloons (expandable to 8-in. diameter)*
- 300 *wooden coffee stirrers*
- 300 *wooden splints*
- 50 *pressure-sensitive 1" × 3" labels*
- 5 *gr bromothymol blue powder, sodium salt*
- 1 *lb mossy zinc*
- 5 *pt concentrated hydrochloric acid*
- ½ *lb potassium iodide crystals*
- 2 *lb citric acid crystals*
- 1 *oz magnesium ribbon*
- ½ *lb hydrated lime powder*
- 1 *lb limestone chips*
- 6 *pieces soft glass tubing, 8 in. long*

MATERIALS TO BE OBTAINED LOCALLY

The following equipment is to be obtained locally. While this may be a minor nuisance for some, it does give you greater budgetary flexibility and may save duplicating some common equipment. Certain items—such as Alka-Seltzer tablets and hydrogen peroxide solution—need to be purchased fresh; they deteriorate when stored for a long time. You may want to buy all these materials, borrow some, or have the children bring them in. The total cost of this group of items should be around $10.

- *1 yardstick*
- *15 paint buckets, pails, or containers, roughly 1-gal size (for water and waste)*
- *1 gal white vinegar*
- *4 lb baking soda*
- *1 qt household ammonia (clear recommended)*
- *7 pt hydrogen peroxide, 3% or 6% solution (10-volume or 20-volume)*
- *1 pkg wooden safety matches (10 small boxes)*
- *30 small jars (such as baby-food jars) for dispensing baking soda and citric acid*
- *old newspapers*
- *1 quart bottle with cap (such as a vinegar bottle)*
- *sponges*
- *1 jar soap-bubble solution or liquid detergent*
- *1 roll aluminum foil (25 ft)*
- *1 ball string*
- *2 paper pie plates (for balance pans)*
- *Alka-Seltzer tablets, 2 to 4 per student*
- *oyster or clam shells*
- *10 lb Dry Ice*
- *hammer and cloth gloves to handle Dry Ice*

Note: If you want to explore filling balloons with helium (see page 29), you may be able to borrow a cylinder from a science laboratory in a university or industry. Helium also comes in small containers. One source is Jericho Industries, Charlotte, North Carolina 28203.

Activities

Work with Bromothymol Blue (BTB)

MATERIALS

For each student:

3 1-oz medicine cups
1 eyedropper

For each group of 4 students:

*1 2-oz plastic squeeze bottle of BTB**
1 4-oz plastic squeeze bottle of vinegar
1 4-oz plastic squeeze bottle of dilute ammonia
newspapers
sponges
extra medicine cups

You should have the above materials assembled and the solutions prepared prior to the beginning of class. Before you begin, spread newspapers out on desks and have sponges available for the inevitable spills and messes.

When all the groups have a supply of materials, suggest that each student take a little of each liquid in a medicine cup. Urge the students to use the eyedroppers. Ask them to see what happens when different liquids are added to one another, drop by drop.

Sooner or later, some student will claim that the BTB has turned from blue to orange or yellow.

"Oh look! Drop BTB in vinegar and it turns yellow."

"BTB in vinegar, and it eats it up!"

Can you turn it back to blue again?

"Ammonia is stronger than vinegar."

*See Appendix for instructions on preparation.

"I like ammonia 'cause it saves you from vinegar."

Is there a color "between" blue and yellow?

"I don't know, but I'll find out."

"I got five shades of green."

You will need to have waste buckets handy for each group, so that they can empty their cups and start again.

"I'm trying to figure out how I can get the ammonia white again."

"Can I take fresh stuff and try it again?"

"I wonder if that's ammonia. I'm afraid to smell it because it stings my eyes."

How does the ammonia solution feel? Take some on your finger and rub your thumb and finger together. How about vinegar?

What do the liquids taste like? (Ammonia is poisonous to drink. To taste it safely, wet your fingertip with ammonia and touch your tongue.)

"Sharp."

"Strong."

"Sort of sweet and sour."

"Nothing."

After the students have worked with these materials for about a class period, you might take a few minutes to share experiences and talk. The questions *How do you turn BTB yellow?* and *How do you turn it back to blue?* might reveal some disagreements among the students. If so, let the students present their evidence. If they still disagree, urge them to go back to the materials again.

What does spit do to BTB?

More BTB, and Carbon Dioxide

MATERIALS

For each student:

3 2-oz medicine cups
1 eyedropper
1 6" × 1" plastic vial
wooden coffee stirrers

For each group of 4 students:

buckets for water and for waste
2 ¼-tsp measuring spoons
2 ½-pt jars or baby-food jars
(jar citric acid, labeled)
(jar baking soda, labeled)

Have available the materials from the previous activity. You may want to tie the measuring spoons to the jars. Work on newspapers and keep sponges available. Have the gas collection equipment (next section) in reserve. If your room has no sink, you can use the buckets to bring in water and handle waste water. One-gallon polyethylene pails are cheap to buy and easy for students to handle. Clean two-pound coffee cans or milk cartons can be used.

You might start off by asking the students to put a little citric acid powder (about ¼ teaspoon) into one of the medicine cups. Add some water to it, and stir. What happens? Where did the citric acid go?

"Hey, it disappeared."

"Citric acid leaves the water clear."

What does the solution taste like?

"Tangy."

"Oooh, it's bitter."

What do you think the citric acid solution will do to a BTB solution?

In one class, students added some sugar to their citric acid and made "lemonade." It is all right to drink this mixture if you add lots of water to dilute the acid enough so that it doesn't taste too sour.

Students with sensitive stomachs can develop a stomachache from too much acid. Usually a drink of water will set that right, but a little baking soda is sure to help.

Will the baking soda dissolve as the citric acid did?

"Baking soda turns the water white."

What effect does a baking soda solution have on BTB? On citric acid?

Once you have introduced baking soda, it won't be long until someone discovers how to make it fizz. This activity will dominate many children's interest for a

while. Others may stick with making the BTB change colors.

What do you think would happen if the baking soda-and-acid mixture started fizzing? What would happen if it was in a closed space? Many children will be mystified.

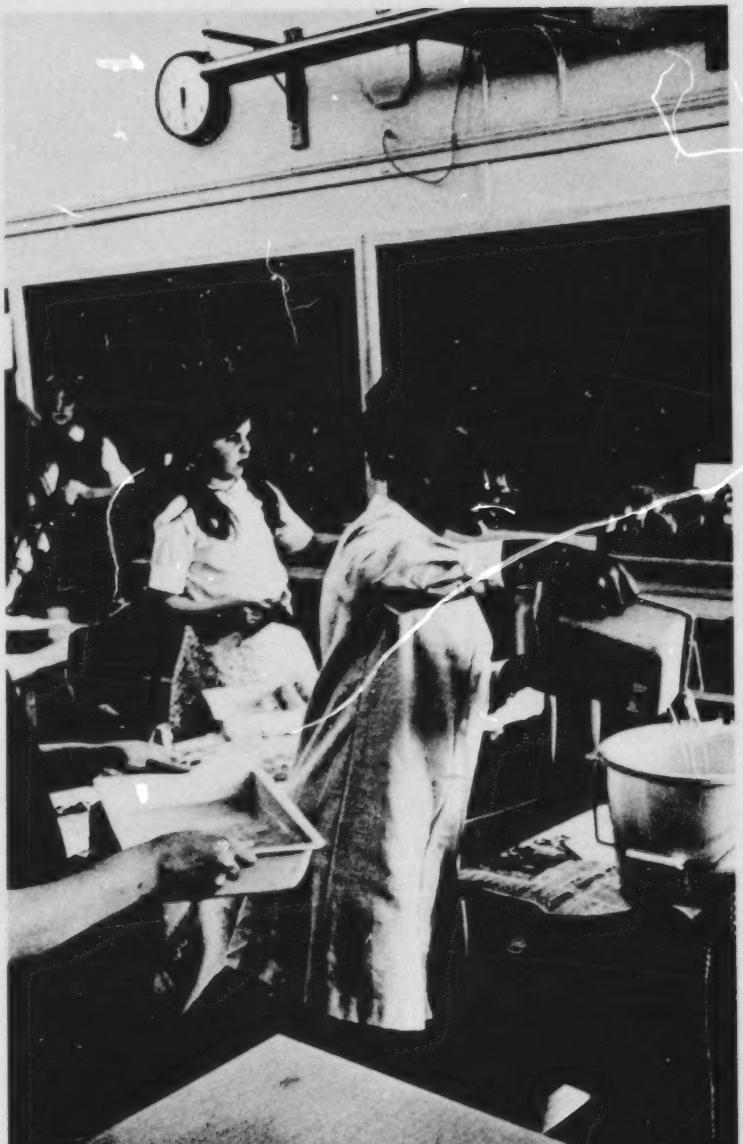
"Wow! Look at all that fizz. I didn't know it had such power."

Some of the students will know that a gas is being generated. Can they suggest a way to collect the gas?

Some students are excited by the fizzing or by the very active reaction and try to make bigger fizzes by dumping together everything they can get their hands on. You might urge them to try to collect the gas – or to make the layered cylinder described below. Let them know you have only a limited supply of materials.

Those students who continue working with the BTB and the acids and bases sometimes come to a dead end and can use a suggestion. Here is one that might be useful:

Use the 6-inch cylindrical plastic vial. (A narrow drinking glass or olive jar will do.) Put about ¼ inch of baking soda in the bottom of the vial, and pour on top of that about an inch of BTB solution. Don't mix them. Now add vinegar as gently as possible, trickling it slowly down the side till you've added about 3 inches of vinegar. With luck, the mixture will layer and give a beautiful slow reaction that is fascinating to watch and fun to work with.



Collecting and Testing Carbon Dioxide

MATERIALS

*Erlenmeyer flasks**
balloons (about 3 per student)
balance with yardstick beam (See Appendix for construction details.)
paper clips
2 *1-hole rubber stoppers per flask*
4-in. stiff plastic tubes to fit the stoppers
wooden safety matches (small boxes)
wooden splints
hand pump

*The Erlenmeyer flasks with the collection apparatus attached tip easily. They are more stable if placed inside heavy jars, such as peanut butter jars.

Have on hand all the materials used till now. To prepare the balance ahead of time, get a yardstick and have three holes drilled in it, as specified in the Appendix. Also, have a look at page 42 in the Appendix, which shows how to weigh fractions of a paper clip, using a balance-beam rider.

Give those students who want it an opportunity to try to collect the gas in their own way. Occasionally, a student will come up with an ingenious idea. Most often, however, students won't, but their fumbling around and their unsuccessful efforts will tell you a great deal about what they think a gas is, and how

they think it behaves. (The Appendix has instructions for collecting a gas.)

If students want some ideas, you can suggest that they put a dry mixture of ½ teaspoon each of baking soda and citric acid into a flask, add about 2 ounces of water, and then quickly put a balloon over the top of the flask.

What happens to the balloon?

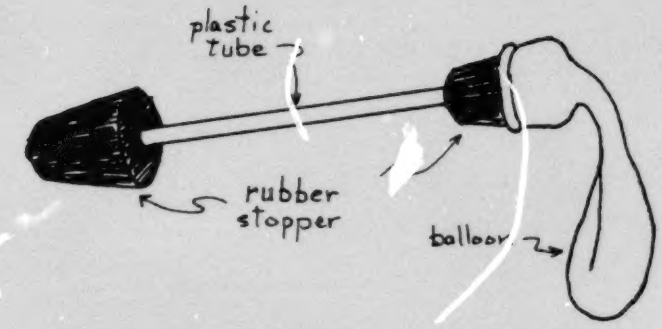
Don't be surprised if quite a few students want to do this, once they see what happens.

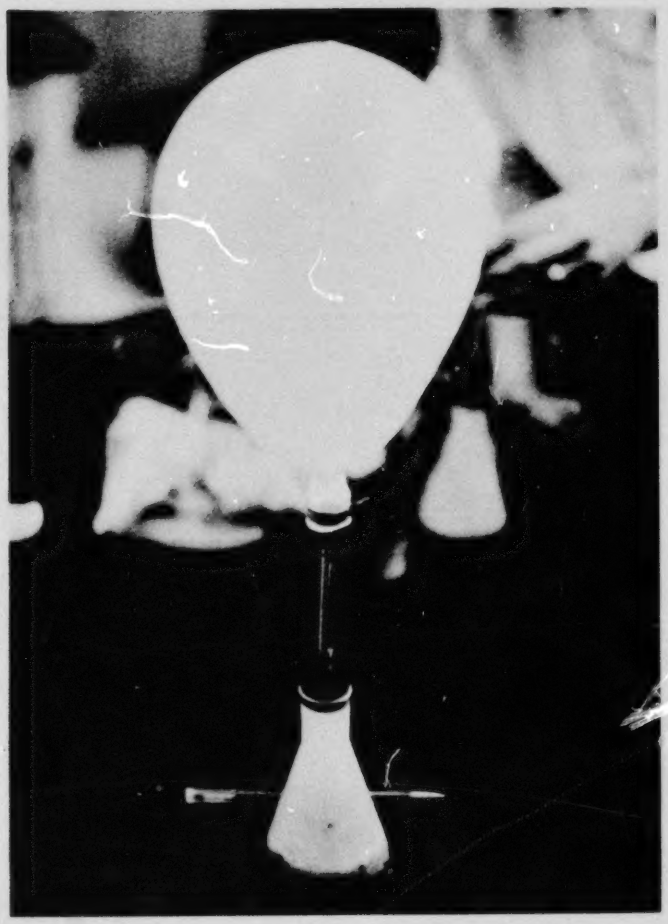
What can you do with a balloonful of gas?

In one class, some boys ran races by dropping two balloons at the same time, one filled with carbon dioxide and one filled with room air. They said the carbon dioxide won because it was "heavier."

You might challenge the students to find out if a carbon dioxide balloon is really heavier than an air balloon. If you have a balance with a yardstick beam (see diagram in Appendix for construction details), the balloons can be accurately weighed.

How much heavier . . .?





Does it depend on how full the balloon is?

How much does air alone weigh?

"I thought the air would weigh more, but the gas is more."

The hand pump can be used to fill a balloon with room air.

In order to perform some of the chemical tests with carbon dioxide, it is convenient to have a more permanent collecting device. Use the stiff plastic tubes in the *Kit* that fit into the one-hole rubber stoppers. These rubber stoppers will fit the Erlemeyer flasks. The accompanying diagram shows how to connect things.

With this device, it's easy to do the BTB and limewater tests and to collect enough gas for several flame tests. Be sure to use plastic tubes. Pushing glass tubes into rubber stoppers may break them.

"If your balloon is straight, the gas goes in easier."

Children often comment that the flask feels colder as the reaction goes on.

When the balloon is full, or the reaction in the flask has stopped, twist the balloon and press your fingertip on the top end of the tube to prevent the gas escaping. Then remove the entire collecting device from the flask.

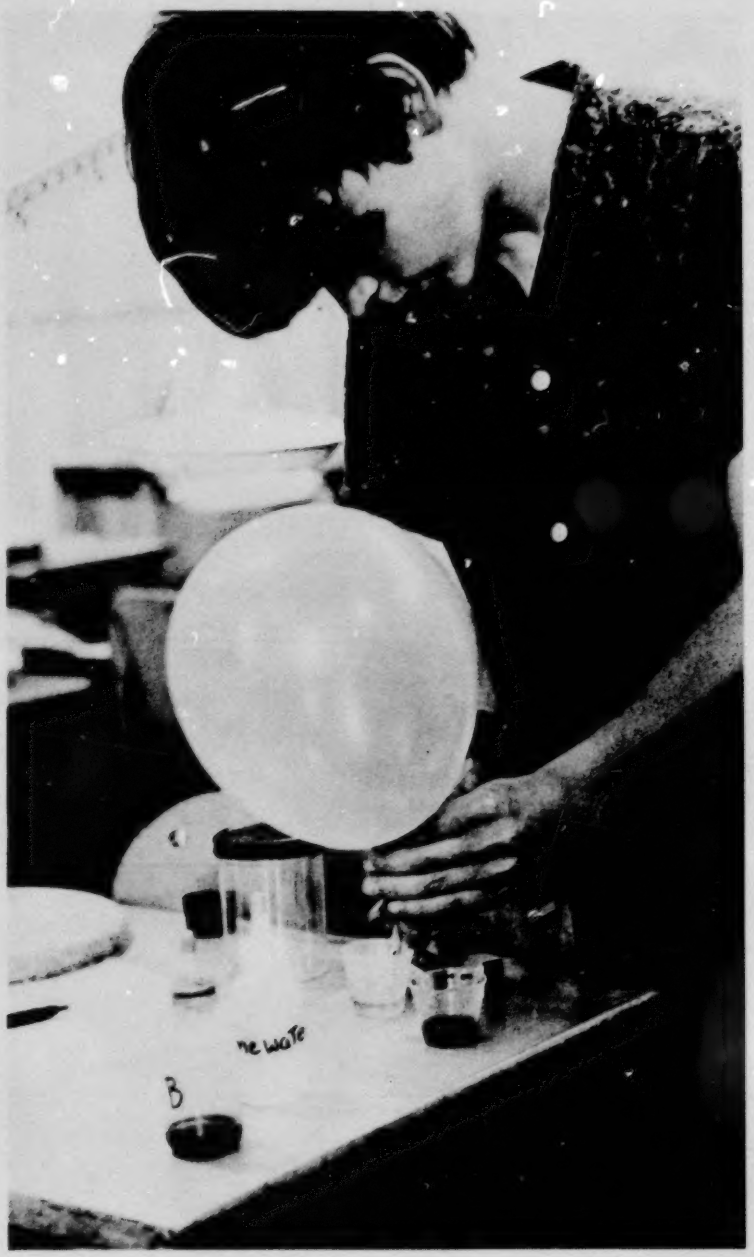
BTB Test

To do the BTB test, pour about 5 cc of BTB solution in the bottom of a clean medicine cup or small glass. The BTB should be blue or blue-green. Then put the bottom end of the collector tube, still attached to the balloon of gas, into the BTB, and allow the gas to bubble gently through the BTB. Control the bubbling by pinching the neck of the balloon.

If you have carbon dioxide in the balloon, the BTB will gradually turn from blue to yellow. You can repeat the test with the same BTB by using a few drops of dilute ammonia solution to turn the BTB blue once again. Don't use too much ammonia, or it will take a great deal of carbon dioxide to turn the BTB yellow again.

If you bubble air through BTB what happens?

Several things can go wrong with this test. You can have the BTB *too* basic, that is, "too blue." (The BTB should turn yellow with the addition of one or two drops of vinegar.) Another thing that can happen is that you may get acid in the collector tube, and the acid alone will turn the BTB yellow. This usually happens when a vigorous reaction spatters liquid up into the tube. Rinsing the tube before you put it in the BTB will take care of this. Still another problem arises when children shake their tubes and get the balloon full of the reaction mixture. Helping such children acquire a more refined experimental technique can be quite challenging!



Limewater Test

The limewater test is carried out in the same way as the BTB test. Place about 5 cc of limewater in a clear, clean container and bubble the gas through it. Carbon dioxide turns limewater milky.

"Look what happens when I put gas in limewater. It turns whitish. Alka-Seltzerish."

"The limewater has all these little crystals in it."

Is the limewater reaction reversible, like the BTB test?

What does room air or your breath do with the limewater test? With the BTB test? Is there much carbon dioxide?

"I blew into limewater once, and it turned cloudy."

Flame Test

What effect does carbon dioxide have on a flame?

A splint will burn in air. Will it burn in carbon dioxide?

What can you collect the gas in so you can test it and see what happens?

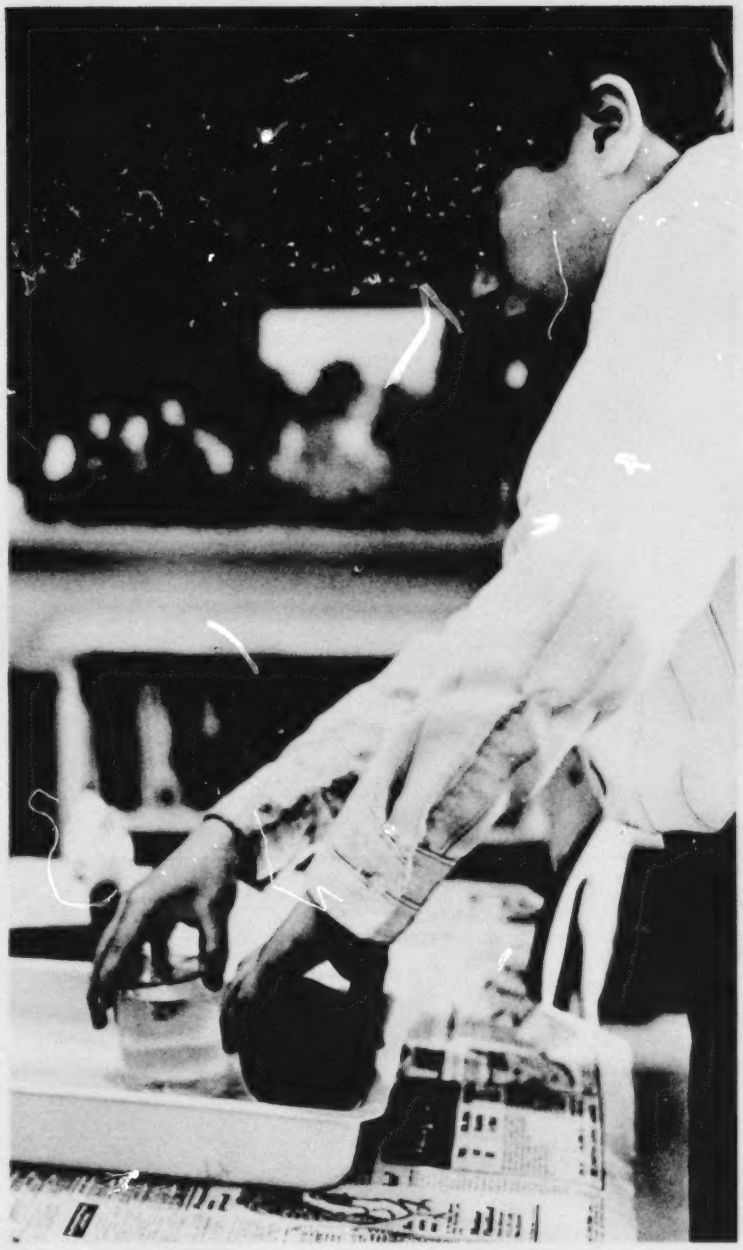
In one class, students suggested putting a flame near the mouth of a gas-filled balloon and letting some gas come out or thrusting a flaming splint into the balloon. Others objected that the moving gas would put out the flame or that the gas would escape when a splint was put into the balloon opening.

One way to simplify a flame test is to collect the gas in a jar. Half-pint plastic jars are provided in the *Kit*.

How can you fill the jar with pure carbon dioxide that isn't contaminated with air?

Here is one method that works. Fill a bucket or a pan about three-quarters full of water. Put the jar in the bucket so that it fills up completely with water, turn it upside down, and raise it so that most of the jar sticks out of the water but water stays in the jar.

To get the carbon dioxide gas from the balloon into the jar, put the bottom end of the collector tube into the water directly under the jar and, by relaxing the pressure of your fingertip on the top end of the tube, allow the carbon dioxide to bubble slowly up inside the jar. When the jar is filled with carbon dioxide (that is, the water has been forced out of it), cover it, while it is still



under water, with the lid or with anything flat that seals the top. Then remove the jar from the water.

To do the flame test, the students take a burning splint, remove the lid from the jar, and dip the splint into it.

What happens to the splint?

What happens to the splint when the jar has room air in it?

A girl in one class argued that the flame went out because it couldn't get any air in the jar. She repeated the experiment with an air-filled container.

The flame test provides a method for testing where the carbon dioxide is. Take the lid off the jar of carbon dioxide. Pretend that the carbon dioxide is a thick, viscous liquid that pours very slowly.

Can you pour the carbon dioxide into another jar?

You can use the flame test to see if you've succeeded.

The next activities involve making and testing oxygen. You will probably want to go on to these activities after the students have made carbon dioxide, have done the BTB and limewater tests with it, have collected a jarful of the gas, and have done the flame test.

Exploring Oxygen

MATERIALS

5 *pt 3% hydrogen peroxide solution (or 3 pt 6% hydrogen peroxide solution)*
½ *lb potassium iodide*
gas production and collection equipment
wooden splints
wooden safety matches (small boxes)

Have on hand all the materials used up till now.

What is the air we breathe?

Many students reply that it is oxygen. In fact, air has only a small percentage of oxygen in it. Here is a way to make pure oxygen.

Into the flask or bottle you use for gas generation, place about ¼ teaspoon of potassium iodide crystals. Add 3 ounces of 3% hydrogen peroxide solution (or 1½ ounces of 6% solution). Place the balloon-and-tube collector in the flask after a few bubbles have come up. In five to ten minutes the reaction will be finished, and there will be enough oxygen in the balloon for the tests. (The light brown color in the flask is from the iodine. This will stain clothes and other things. In one class, a student got iodine all over his shirt. His mother got it out with hydrogen peroxide.)

Does oxygen have the same properties as air?

What does oxygen do if you bubble it through BTB or limewater the way you did carbon dioxide and air?

How does the flame test work with a jarful of oxygen?

After the students have tested a flaming splint in oxygen, have them try a glowing splint. Get the end of a wooden splint burning well; then blow it out. Usually the end will continue to glow red. Insert the glowing splint into a freshly collected jar of oxygen. What happens?

Can you repeat this test using the same jar of oxygen?

Does oxygen "pour" the way carbon dioxide does? Which is heavier, carbon dioxide or oxygen? How can you tell?

Some students might become interested in the reaction that produces the oxygen.

To get more oxygen, should you use more hydrogen peroxide or more potassium iodide?

What effect does the amount of potassium iodide have on the speed at which the oxygen is produced?

If you warmed or cooled the hydrogen peroxide solution, would this have any effect on the reaction?

Children talk about the fact that the flask itself feels hotter as the reaction proceeds. Some recall that it got cooler when they were making carbon dioxide.

In one class, a student suggested this experiment.

> "Can I do this? I want to put potassium iodide and hydrogen peroxide to make oxygen in one balloon and put citric acid and baking soda to make carbon dioxide in another balloon, and then put all the gas together and see what happens in the flame test."

The ESS unit GASES AND "AIRS" offers additional ideas for work with gases and suggests a method to determine the amount of oxygen present in a gas mixture.

Work with Hydrogen

MATERIALS

- *mossy zinc*
- *dilute hydrochloric acid (4 molar – see Appendix)*
- *paper clips*
- *safety glasses (for those who do not wear eyeglasses)*
- *gas production and collection equipment*
- *balloons*
- *string*
- *balance (see Appendix for assembly instructions)*
- 2 *paper pie plates*
- *yardstick beam*

You will probably want to reread the sections of the Appendix dealing with safety. Be sure each student is wearing comfortable safety glasses or his own eyeglasses.

Place the balance with pans where students can reach it easily to weigh their zinc.* See the Appendix for instructions on assembling the balance.

Prepare the diluted hydrochloric acid ahead of time. Have only the dilute acid available to the students, and put the concentrated acid away. Be sure to label the acid bottles, indicating clearly which is dilute and which is concentrated.

Put the *dilute* hydrochloric acid where students can conveniently get to it, without crowding. Since there is bound to be some spillage, have on hand paper towels, water for washing hands, and baking soda to neutralize spilled acid.

*If there are other balances around your school, you might have a couple of them available for weighing out the zinc, and reserve the yardstick balance for investigating the weight of the balloons.

The production of hydrogen often creates excitement among the students. To begin the class, you may want to have a brief review of safety precautions and of classroom procedures. Tell the students that they are going to be able to make hydrogen, using zinc and hydrochloric acid (also called muriatic acid). Point out that the acid you are using in the class has been diluted (two parts water to one part acid) and that wearing some kind of glasses will protect the eyes from spattering. However, stress that the students must be careful.

In making the hydrogen, the students should first weigh out the zinc and place it in the empty flask. Then they should measure out and pour in the dilute hydrochloric acid. Tell them to wait a few seconds after the reaction begins before putting on the gas collector, so that the hydrogen can drive the room air out of the flask.

Use about 8 grams of zinc (equal to about 12 #1 paper clips in weight) and 2 ounces (60 cc) of the diluted hydrochloric acid.

Mossy zinc varies widely, so that the reaction time may vary from five minutes to half an hour. Caution the students not to shake the flask, since this will cause acid to bubble up into the balloon. A swirling action will suffice to "mix" the materials.

When the bubbling has ceased and the reaction has almost stopped, the balloon can be removed and tied off. A piece of string tied to a balloon will help the student hold onto it.

Can you determine how much acid remains in the solution in the flask when the reaction has finished?

If you add BTB to the solution, what color does it appear?

How many drops of ammonia does it now take to turn the solution blue?

The acid remaining in the flask can be flushed down the drain. Any solid zinc remaining in the flask can be rinsed off with water and returned to the zinc supply.

The floating hydrogen balloons will probably produce lively confusion in the classroom. Students need time to play with them and a lot of experiences to help them make sense of what they see.

How much string will the balloon lift?

Several worthwhile games have been invented by students. Three boys had balloon races to see whose balloon would get to the ceiling first. Several girls tried to get their balloons to hang in the air, neither rising nor falling.

Can you use hanging balloons to chart the air circulation in the room?

How many paper clips will a balloon lift?

How much does the hydrogen inside the balloon weigh? (That is, what is the weight of the balloon plus hydrogen plus string, minus the weight of the balloon and string?) The yardstick balance is sensitive enough for working on these questions.

After a period of working with the hydrogen, a brief discussion and sharing of thoughts might be useful.

You might use one of the above questions to get a discussion started. Give the students a chance to share their thinking about the experiments and to explore their differences. The question *How much does the hydrogen inside the balloon weigh?* is a particularly good one to explore. When differences arise among the students, encourage them to suggest experiments that might resolve the disputes and, if possible, then give them a chance to go back to the materials.

Flame Test

The hydrogen flame test is spectacular.

Fill a half-pint plastic jar with hydrogen by bubbling it through water. Close the jar with the lid, and remove it from the water. Light a wooden splint and bring the flaming splint to the jar just as you remove the lid. Poof!

The "pop" from a half-pint of hydrogen is safe enough in the classroom. A large amount of hydrogen (several quarts) when mixed with air can produce enough of an explosion to ring your ears. Plastic containers are supplied in the *Kit* because plastic is preferable to glass for this experiment. *Do not* use large (pint or more) glass containers to hold hydrogen.

For another experiment, turn the jar of hydrogen right side up and leave it open for a few seconds before inserting the burning splint. What happens? Will the same thing happen with carbon dioxide?

What effect does hydrogen have on BTB or limewater?

Hydrogen Soap Bubbles

MATERIALS

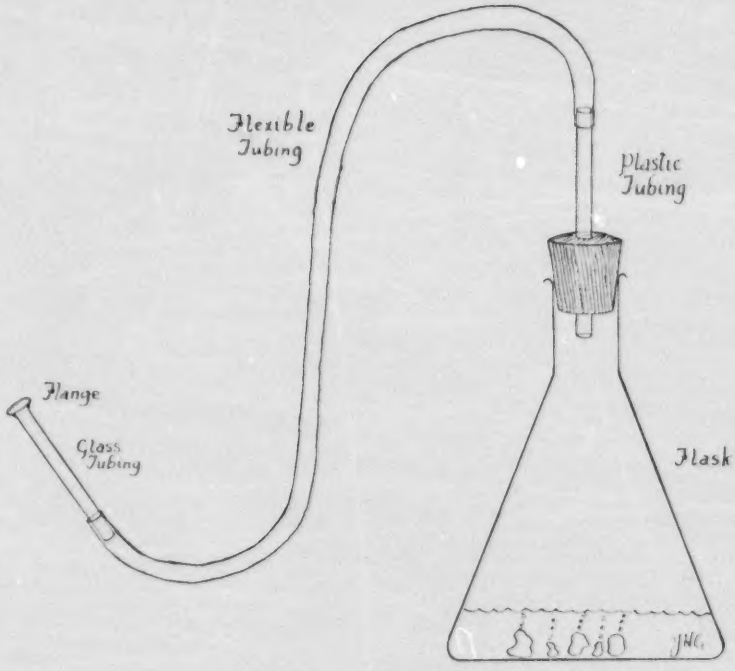
- 6 *8-in. pieces of soft glass tubing*
- 6 *3-ft pieces of flexible vinyl tubing*
- *mossy zinc*
- *hydrochloric acid, dilute*
- *Erlenmeyer flasks*
- *one-hole rubber stoppers*
- *4-in. stiff plastic tubes to fit the rubber stoppers*
- *commercial soap-bubble solution or liquid detergent*

Before the class begins, you will need to make a flange on one end of each piece of the soft glass tubing. To do this, heat the end of a tube in the tip of a flame from a Bunsen burner, propane torch, or gas stove. Rotate the tube so that it heats evenly. When the glass is soft, splay the end of the tube by applying pressure inside the tube with a piece of metal, such as a large nail.

Without the flange on the end, it is often difficult to get the bubble off the end of the tube without breaking it.

The students should continue to wear their safety glasses.

Connect the tubing as shown in the accompanying diagram.



Soap bubbles provide a dramatic and pleasing demonstration of some of the properties of hydrogen. The hydrogen gas is generated in the flask and passes through the flexible tubing. The flanged tube is dipped into a soap solution, and the gas expands the soap film on the end into a bubble. If

you shake the bubble or blow on it, it will leave the tube and rise in the room.

The bubble can be ignited with a lighted splint or match.

"This is terrific!"

"We need more soap because our bubbles are too thin."

"I made five bubbles together."

"Gee, this is the greatest thing I've ever done."

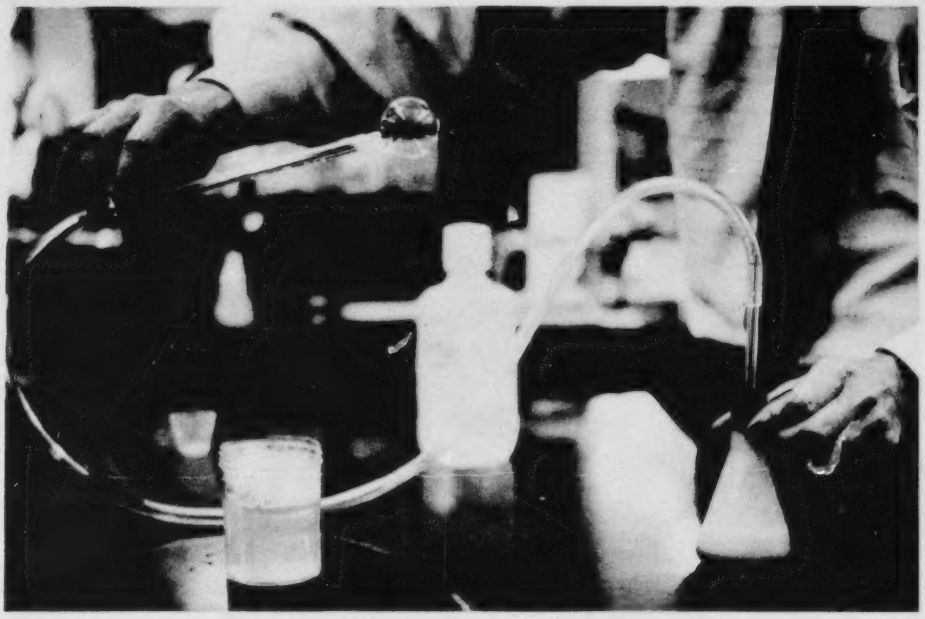
"Every time the bubble blows up, it puts out the match."

"It exploded, and I felt soap splash all over me."

"There's a bubble stuck on the ceiling."

Why do the first few bubbles fall?

What happens with carbon dioxide bubbles?



Mystery Gases

MATERIALS

gas production and collection equipment
medicine cups
BTB
limewater
wooden splints
balance with yardstick arm
dilute hydrochloric acid (4 molar)
vinegar
limestone or marble chips
magnesium ribbon
aluminum foil
Alka-Seltzer tablets (2 to 4 per student)

Have on hand all the materials used up till now.

Now that the students have made carbon dioxide, oxygen, and hydrogen, and have an idea of how these gases behave, you can challenge them with some unknown gases. All the gases produced by these reactions are one or another of the three gases they have already explored, but you needn't tell the students that.

It is up to you to decide the best way for your class to work at mystery gas activities. You might have the whole class tackle one mystery gas at a time, or you might have several different mystery gas reactions going at once. For convenience, you will probably want to have the whole class work with Dry Ice together.

MAGNESIUM RIBBON

Cut off about 2 feet of the magnesium ribbon. Put about 1 ounce of dilute hydrochloric acid in the flask, and add the magnesium ribbon.

What is the gas produced?

Will magnesium ribbon react with vinegar? What is produced?

LIMESTONE OR MARBLE CHIPS

Place enough of the limestone or marble chips in a flask almost to cover the bottom. Add 2 ounces of dilute hydrochloric acid.

What gas is produced?

To produce a larger quantity of gas, would you add more chips or more acid?

What happens if you use vinegar instead of the acid?

ALUMINUM FOIL

Cut a strip of aluminum foil about 6 inches square, fold it up into a small, flat package and place it in the flask. Pour about 2 ounces of dilute hydrochloric acid into the flask.

What gas is produced?

(This reaction often takes a while to get started, but once begun, it goes quite vigorously.)

ALKA-SELTZER TABLETS

Place some water in a flask, and then drop in an Alka-Seltzer tablet.

What is the gas produced?

Do two tablets give twice as much gas as one?

What effect do the tablets have on the water temperature? Does the tablet behave the same in ice-cold water? In warm water?

SEASHELLS

If you have a supply of oyster or clam shells available, put in the flask about 20 grams (1 ounce by weight) of shells, and add 1 ounce (liquid measure) of dilute hydrochloric acid.

What gas is produced?

DRY ICE

You will need the following materials:

Dry Ice slabs (Obtain from hospitals, colleges, or ice-cream vendors; 10 pounds is plenty.)
cloth gloves
hammer
gas collection materials
paper cups

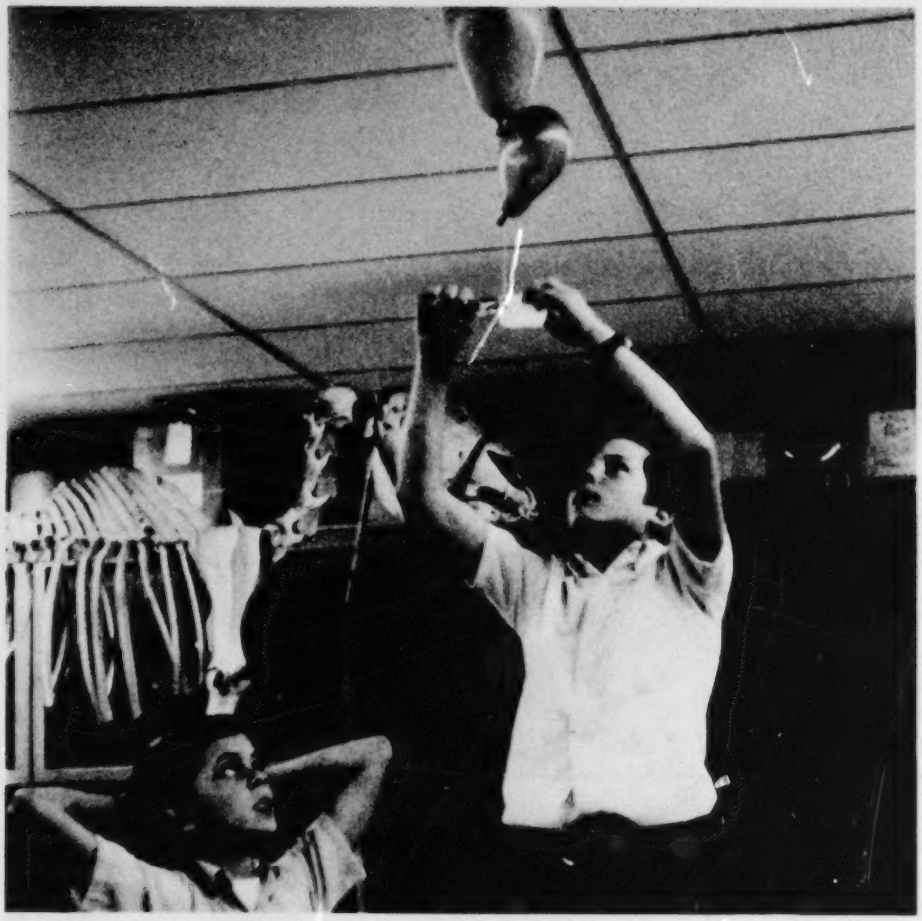
Purchase the Dry Ice as close to class time as possible. It can be kept for a day or so if wrapped in newspaper and stored in a Styrofoam picnic cooler or, better yet, in a freezer. Keep it in the newspaper wrapper, even in the freezer.

With gloves or some other protection for your hands, place one of the Dry Ice slabs in a bag and break it into small pieces with a hammer.

Since Dry Ice is fascinating to experiment with, give the students a small supply and time to explore its possibilities. Provide them with paper cups and water, and tell them to drop small pieces of Dry Ice in the water. The bubbling and vapors that follow are exciting to see and talk about.

The gas collectors should be available, so that students can try to collect and identify the gas evolved when they are ready.

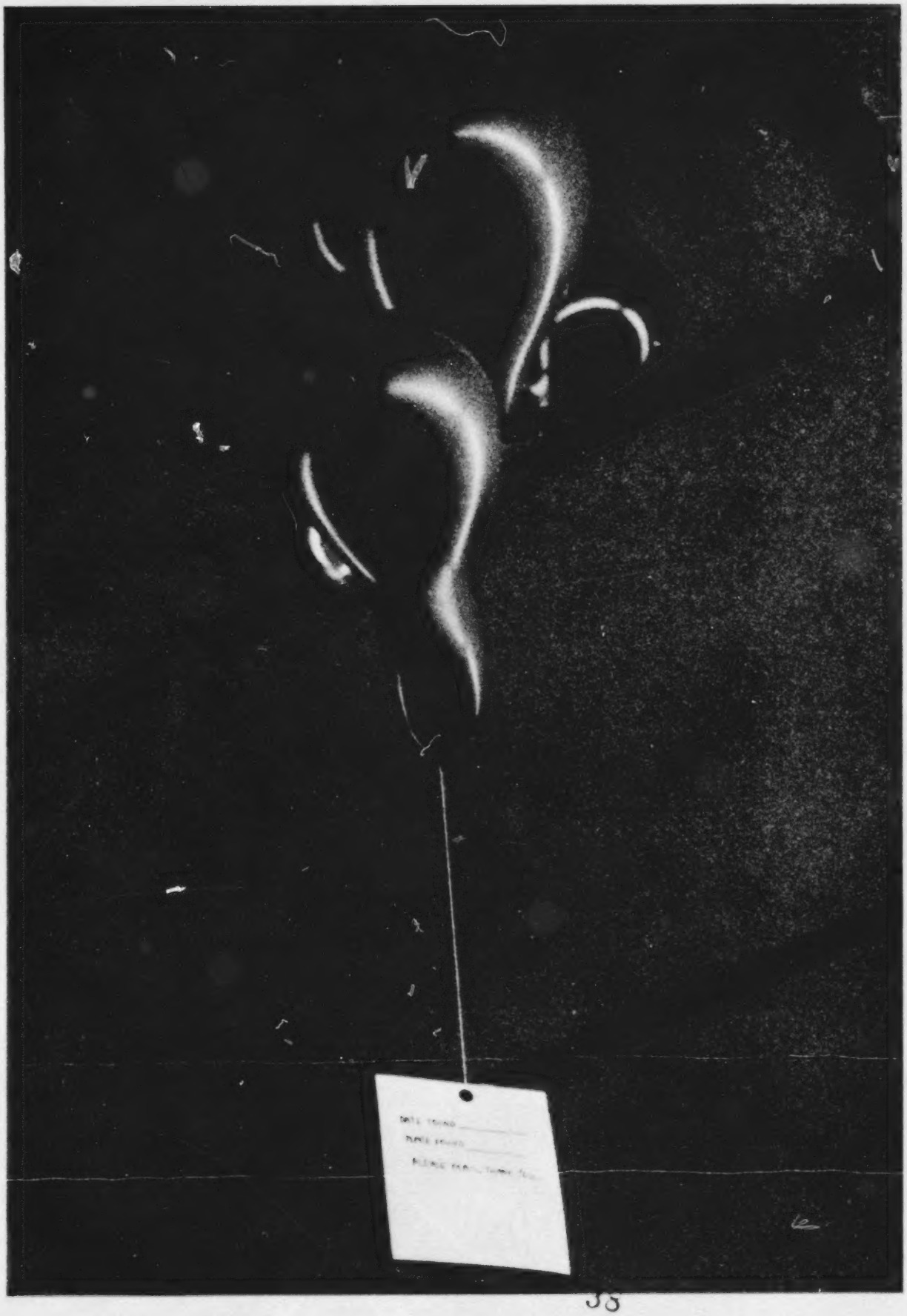
"Balloons Aloft"—A Finale



In one school, several classes ended the unit by sending up balloons with postcards attached. The postcards, addressed to the school, contained the request that the finder write down when and where he found them. One class ran out of zinc and hydrochloric acid to make hyrdogen for the balloons. They borrowed a cylinder of helium from a nearby science laboratory.

Here is what their teacher wrote:

> The kids were in high gear and really excited over the prospect of "balloons aloft." In the end, we managed to get five postcards (cut in half and some cut even smaller) airborne. Whether or not any will ever get through the mail and back again remains to be seen. They'll probably get lost in the mountains.



Appendix

Safety Precautions

Safety Glasses

In this unit, the students and the teacher should wear safety glasses or eyeglasses when handling hydrochloric acid or when making and testing hydrogen. The chief danger is of spattering acid into the eyes.

There are 15 pairs of safety galsses in the *Kit*. Students who wear glasses can continue to wear their own glasses. Schools often have a supply of safety glasses.

It is important that the safety glasses be comfortable and that they fit snugly on the students' heads. If they aren't comfortable, they won't be worn continuously. If they don't fit snugly and fall off easily, they become a hazard. In one class, the *only* acid spills resulted from students' safety glasses falling off their faces and knocking over the flasks.

Glass Tubing and Jars

The tubing to be used with the one-hole rubber stoppers is plastic. While it is possible to use glass tubing, it is not advisable. A very common laboratory accident occurs when you try to put glass tubing into a rubber stopper. The glass tubing is easily snapped off and pushed through your hand.

There are plastic jars supplied in the *Kit*. It is wise to use these to do the flame tests – particularly hydrogen. A large amount of hydrogen mixed with air can give enough of an explosion to shatter a glass jar, so *do not* collect hydrogen in a large glass container (1-pint or larger).

Acid

The acid supplied in the *Kit* is concentrated. When you handle it, *wear safety glasses*. Have only the dilute acid available to the class. Keep the concentrated acid put away. Label the bottles clearly.

When you dilute the acid, pour acid into water, not the reverse.

The general rule for acid spills or splashes is *plenty of water*. Spills are nothing to panic about. The dilute acid used in this unit will not even affect your skin if washed off immediately. Baking soda can be used to neutralize any acid spilled on the floor or furniture. Sprinkle baking soda on the acid until it stops bubbling, and then clean up the mess.

If you pour acid down the drain, follow it with plenty of water.

If there is no sink in your room, have a bucket of clean water on hand for emergencies.

Labeling

One of the most common laboratory accidents is caused by getting the wrong bottle. This can be avoided by having all bottles and jars clearly labeled. Labels are provided in the *Kit*. They should be put on the jars and bottles before class time.

Preparations, Recipes, and Techniques

The following is a collection of descriptions of preparations, recipes, and techniques. They are gathered together here for convenient reference. Many of them repeat information already provided earlier.

Preparing the Liquids

1. Bromothymol Blue Solution (BTB)

Supplied in the *Kit* is a powder which is the water-soluble sodium salt of bromothymol blue (sometimes spelled bromthymol). For present purposes, you will need a 0.04% solution of BTB. You can make this solution in the pint, narrow-mouth plastic bottle. Put about 0.2 gram of the powder (a little less than the size of a pea) in the bottle. Fill the bottle with clean water, cap it, and shake it to dissolve the powder.

BTB solution is an indicator of the acidity of a solution, and it changes color in the pH range 6.0 to 7.6. It is yellow in the acid range (low pH) and blue in the base range (high pH). If the solution you make is not blue, it is because the water is slightly acidic. To turn the BTB solution blue, add dilute household ammonia (see below) to it, one drop at a time, until the solution is blue. Don't make it too basic. Two drops of vinegar should turn it green or yellow.

2. Ammonia Solutions

The household ammonia which is sold in grocery stores is too strong to work with comfortably. Dilute it for classroom use by mixing four parts water and one part household ammonia. Stir or shake well.

You can also buy household ammonia with detergent added to it. Avoid it if you can, because the detergent will make a lot of bubbles. If it is not possible to get plain ammonia, you can use the detergent solution.

Bottles of household ammonia are labeled "poison." It is poison when and if it is swallowed. It should not, of course, be swallowed. Ammonia fumes irritate the throat. When the ammonia is diluted, the fumes are no longer such a problem.

3. Limewater Solution

Limewater is a clear solution of hydrated lime in water. Hydrated lime is calcium hydroxide powder. It is only slightly soluble in water. To make limewater, put about ½ teaspoon of hydrated lime in a quart bottle (such as an empty clean vinegar bottle), fill it with distilled water or tap water, and cap the bottle tightly. Shake the bottle for a minute or so, and then leave it undisturbed at least overnight. A white powdery precipitate will collect on the bottom of the bottle. This is undissolved lime and insoluble carbonates.

You want only the clear solution. Carefully pour this off into a clean pint bottle (supplied in the *Kit*), disturbing the settled matter as little as possible. Stop pouring before any of the solids come over. You can keep a supply of limewater in the quart bottle and refill the pint bottle whenever it becomes empty. The limewater must be kept tightly stoppered, so that it won't react with the carbon dioxide in the air.

4. Dilute Hydrochloric Acid

The hydrochloric acid (12 molar) supplied in the *Kit*, or available from chemical supply houses, is too concentrated to use safely in the class. To make it 4 molar, you must dilute it by adding one part acid to two parts water and mixing them thoroughly. Tap water will do. *Always add acid to water. Never add water to acid.* There is a great deal of heat of mixing to be dissipated.

The concentrated acid is much more corrosive than the dilute, and it gives off biting, acrid fumes. Be sure to wear safety glasses when you handle it. Label the bottle clearly.

Hydrochloric acid is also called muriatic acid.

5. Hydrogen Peroxide

Hydrogen peroxide can be obtained from drugstores and discount stores. If you buy it from a chemical supply house, get the 3% solution or the 6% solution (sometimes called 10-volume and 20-volume, respectively). Do not get the stronger 30% solution, which can react violently with potassium iodide. Hydrogen peroxide deteriorates if it is not stored properly. It should be kept in airtight containers, in a cool place, and either in a dark place or in an opaque bottle. In the method outlined below, 3% hydrogen peroxide will generate a balloonful of oxygen in three to five minutes. If yours takes longer than that, you may have a stale bottle. Check that your supply is fresh before class time.

Recipes for Making the Gases

1. Carbon Dioxide

Baking soda and citric acid

Place ½ teaspoon of baking soda and ½ teaspoon of citric acid in the bottom of a dry flask. Add about 2 ounces of water. The gas evolved is carbon dioxide. This reaction proceeds quite rapidly and will foam over when larger amounts are used.

2. Oxygen

Hydrogen peroxide (3% solution) and potassium iodide crystals

Place ¼ teaspoon of potassium iodide crystals in the bottom of a clean flask. Pour in about 3 ounces (90 ml) of 3% hydrogen peroxide solution or 1½ ounces of 6% solution. It will take a few seconds for the reaction to get started. The bubbles that evolve are oxygen. The reaction and the materials are safe to handle, but some iodine is produced that may stain clothes or unvarnished woodwork if spilled.

3. Hydrogen

Mossy zinc and dilute hydrochloric acid

Weigh out about 8 grams (12 or 13 #1 paper clips) of the mossy zinc onto a folded piece of paper and pour it into an empty flask. Now add 2 ounces (60 cc) of the dilute hydrochloric acid (4 molar). Have the gas collector ready. (See the following.) The reaction will begin almost immediately. The bubbles that come off are the hydrogen. These quantities will produce a little over a quart of the gas.

Techniques

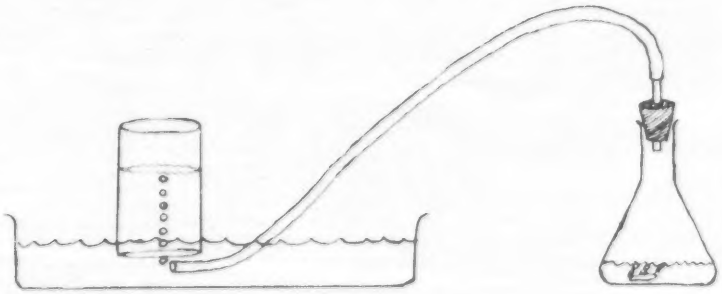
1. *How to Collect the Gas Generated in a Flask*

   (a) The simplest way is just to stretch a balloon over the mouth of the flask. Allow a little time for the air in the flask to be forced out by the gas being generated before you put the balloon on. (A plastic bag and a rubber band can also be used to catch the gas.) When the balloon is full, you can tie it off.

   (b) A more elaborate, but useful, device can be put together with two one-hole rubber stoppers and a rigid tube. Plastic is preferable because of breakage. At least one of the rubber stoppers must fit the flask in which the gas is generated. Put a rubber stopper at each end of the tube. Put one end in the flask, and stretch the balloon over the other end. When the balloon is full, twist the neck, and hold your fingertip on the top end of the tube to prevent the gas from escaping.

This device is useful because it makes it easier to bubble the gas through limewater or BTB, and it is easy to collect the gas in a jar by bubbling it through water.

   (c) If you use flexible tubing with a one-hole stopper in the generating flask, you can collect the gas directly in a jar over water.



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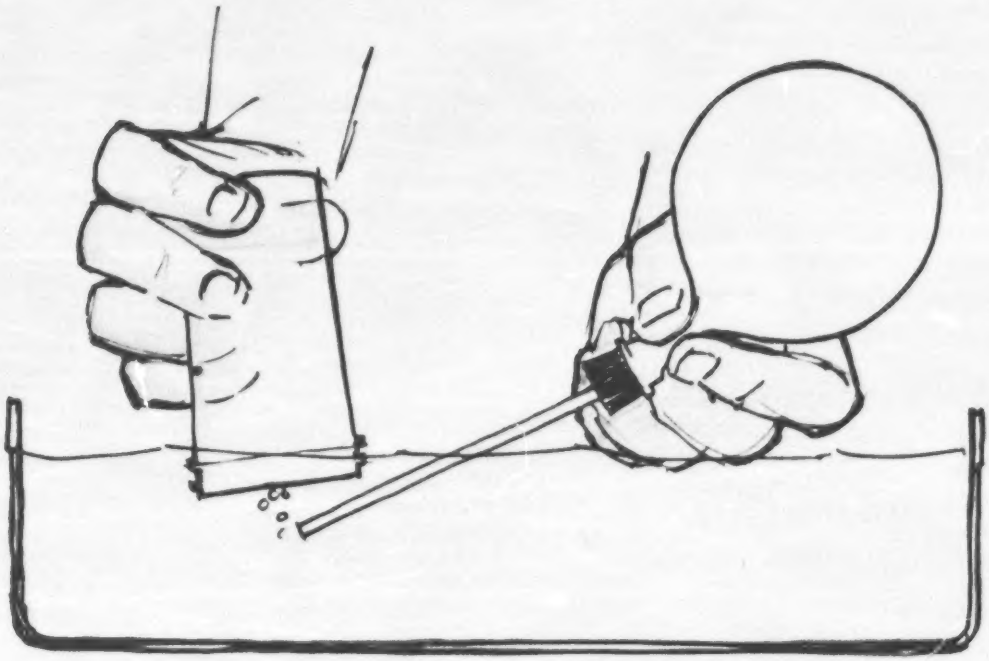
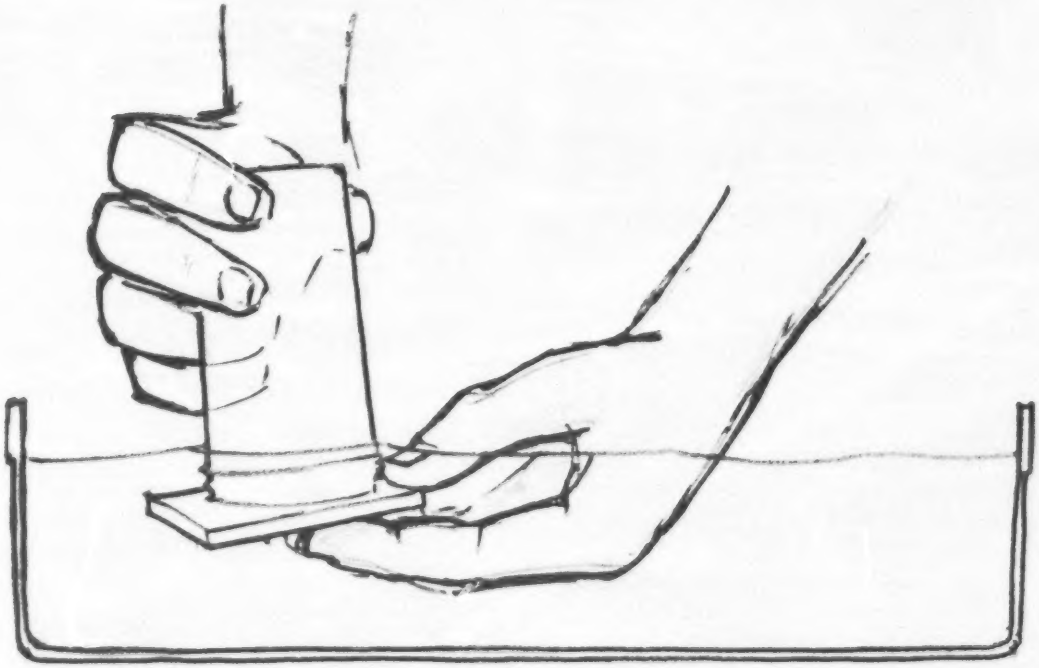


Collect some gas in a balloon. Transfer the gas to a half-pint plastic container by letting the gas push the water out of the container.



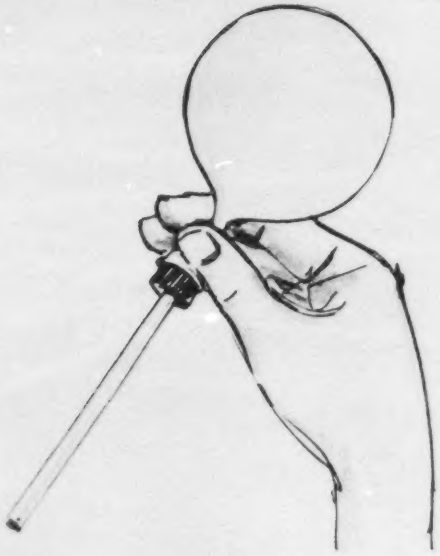
When the container is filled with gas, slide a lid over the mouth of the container and remove it from the water.

2. How to Run the BTB and Limewater Tests

The BTB and limewater tests are performed by bubbling the gas through a small amount of the solution. Use a 1-ounce medicine cup (Make sure it is clean.) Place about 5 cc of BTB or limewater in the cup.

Collect the gas in a balloon-and-tube device (as described above), pinch the balloon shut so that none of the gas will escape, and remove the stopper from the flask. Rinse the bottom of the stopper and the tube with fresh water to remove any of the solution which may have spattered on it. This is necessary, because acid on the tube will change the BTB to yellow, no matter what kind of gas you have in it.

Place the end of the tube just under the surface of the BTB or limewater solution, and allow the gas to bubble slowly through it. In the case of carbon dioxide, the BTB should turn from blue to blue-green to yellow quite quickly. The limewater will turn milky.



Hold the neck of the balloon so that no gas can escape.

Let about half the gas slowly bubble through about 5 cc of BTB. What happens? Let the other half bubble through about 5 cc of limewater. What happens?

3. How to Do a Flame Test

With all the gases made in the unit, it is useful and interesting for the students to see how a flame or a glowing piece of wood is affected. Once you have a jar of the gas, you can test it by uncovering it and dipping in a burning splint.

You can also test with a *glowing* splint. The splint will be extinguished in carbon dioxide but will burst into flame in oxygen. (A splint is simply a thin piece of wood which will continue to glow after the flame is blown out. Matchsticks will not usually do this because they are specially treated. Coffee stirrers and popsicle sticks will usually work.)

With hydrogen, you need to exercise some caution. Hydrogen alone will not support combustion, but pure hydrogen will burn where it contacts air, and a mixture of hydrogen with air or oxygen will explode. A small quantity, such as a half-pint, will only pop, but have the children wear safety glasses.

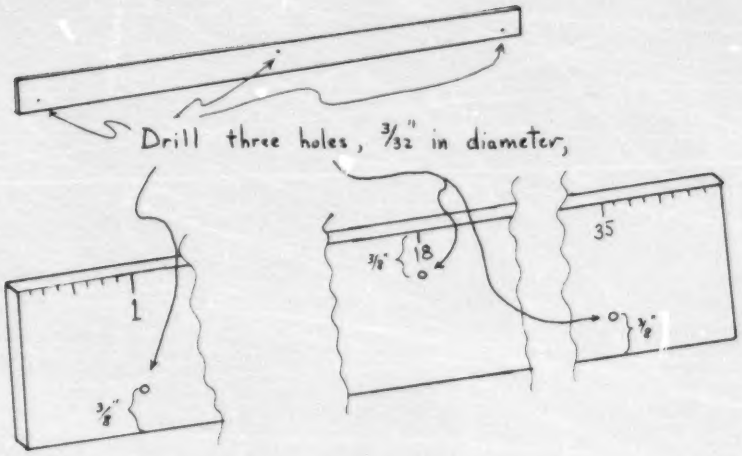
To do the flame test, insert a burning splint into a collected jar of hydrogen. The hydrogen will burn at the mouth of the container where it is in contact with air. The tip of the splint in the hydrogen will not be burning, but it may reignite when it is withdrawn through the burning gas. If air is mixed in with the hydrogen, the gas will pop when ignited. If you are using a small jar, there is such a small quantity of gas that this is not dangerous. Some students recognize the gas as hydrogen when they see it burn or hear it pop.

To do the flame test, remove the lid from the container, and lower a burning piece of wood into the gas.

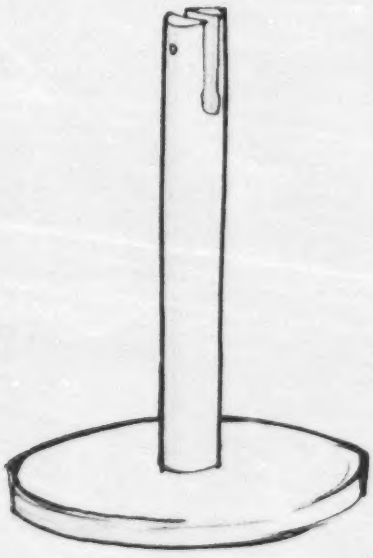
The Yardstick Balance

For a simple balance to be accurate enough to weigh the gas in a balloon, you need an extra-long beam. An inexpensive yardstick from a variety store will work fine. A piece of lath from the lumberyard will do. It should be 36" long, 1¼" wide, and $\frac{7}{32}$" thick. (Ask for 1¼" lattice.)

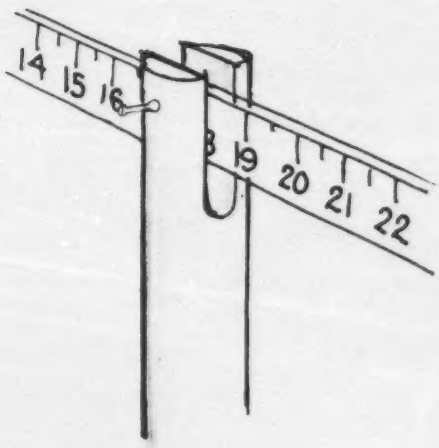
The pans made from paper pie plates are lighter than the plastic ones supplied and increase the sensitivity of the balance.



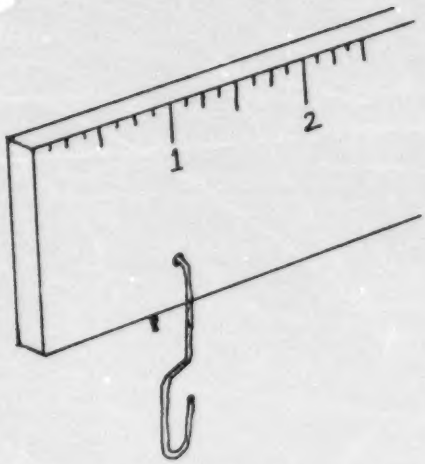
Assembling the Balance



Screw the upright into the base.

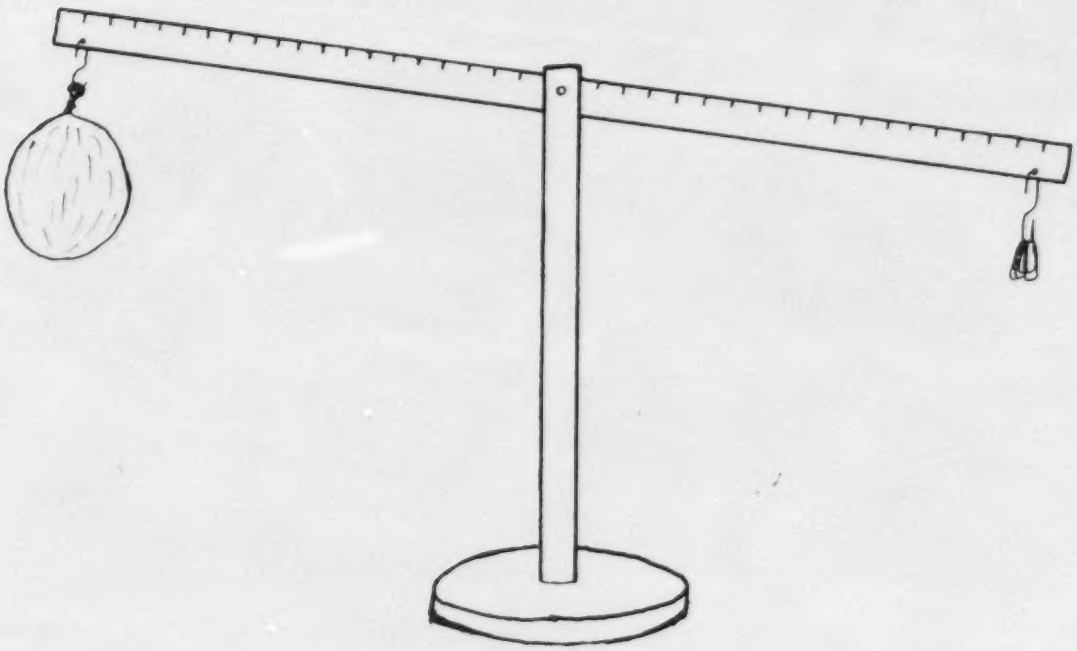


Center the yardstick beam in the slot, and insert the pin through the holes in the upright and the hole in the center of the beam.



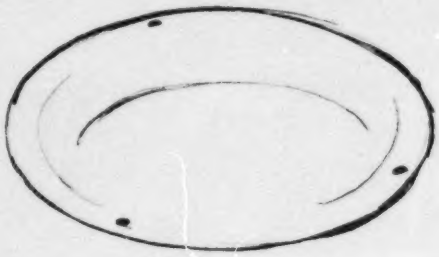
Insert a paper clip through the hole at each end of the beam.

The paper clip should swing freely in the hole. If it does not, bend a larger loop in it so that it does.

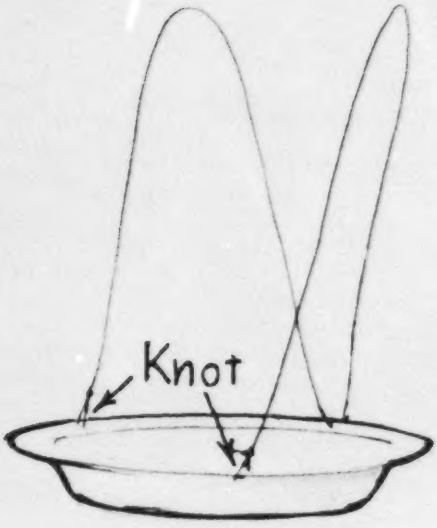


Making Pans for the Balance

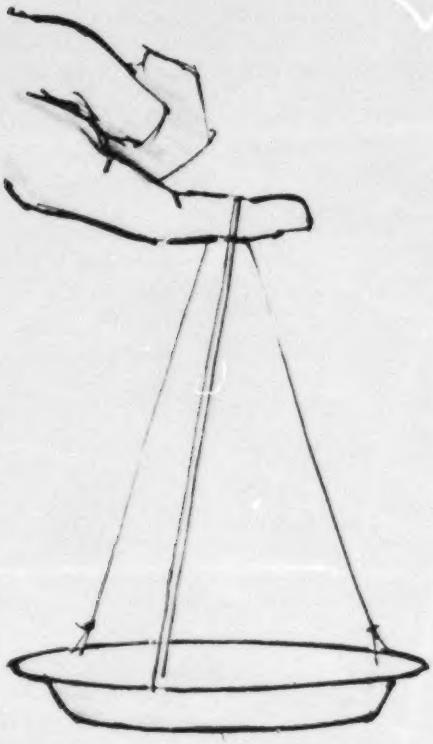
To make pans for the balance, take two paper pie plates and some string.



a. Punch three holes (equally spaced) near the edge of each plate. Use a one-hole paper punch or a sharp instrument.

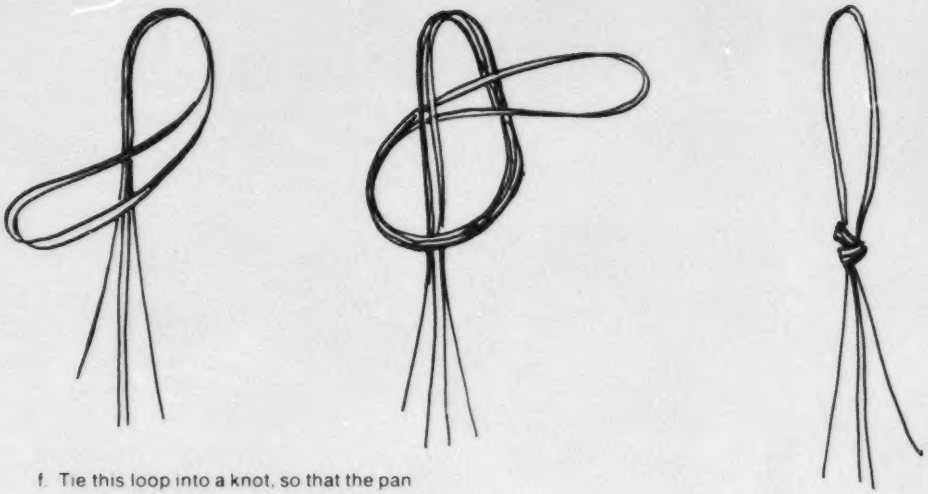


b. Cut two 4' pieces of string.
c. Thread a 4' piece of string through the holes in a pie plate and tie the ends.



d. Insert a finger through the two loops of string and slide the string until the pan hangs level.

e. Pinch off a loop of string near the top.

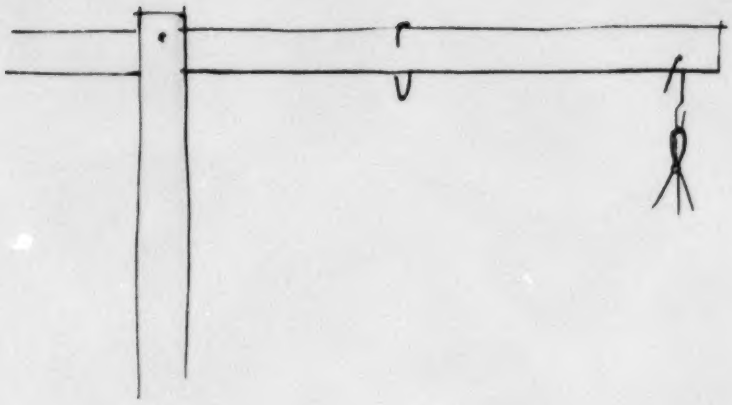


f. Tie this loop into a knot, so that the pan can be hung from the beam.

g. Repeat the above steps for the second pan. Hang the pans from paper clips. If the beam is not level, add a piece of clay to the higher side of the beam.

A Balance Rider

You can use a paper clip at different positions on the beam to weigh things that weigh less than one paper clip. Such a device is called a rider.

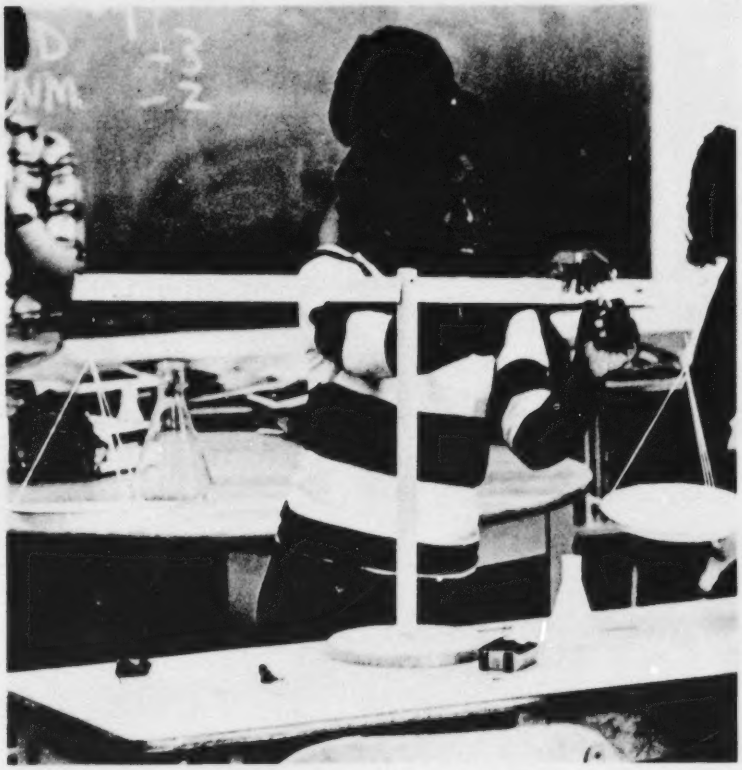


1. Unfold a paper clip. Place it on the beam so that you can slide it along the beam. Where can you place this paper clip on the balance beam so that it balances ½ paper clip in the left-hand pan? (Cut an unfolded paper clip in half.)

2. Can you place the paper clip on the beam so that it will balance ¼ paper clip? How about ⅛ paper clip?

3. Can you now *predict* where to place the paper clip to balance two pieces which together weigh ¼ paper clip? Three pieces which weigh ⅛ paper clip?

4. Is your balance sensitive enough to measure 1/16 paper clip? How can you find out?



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